Final Report

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER, ALABMAA 35812

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for NAS8-36955 Delivery Order #53

entitled

FES\VCGS - HGS/GCEL Optical Studies

by

Gary L. Workman, PhD.

Principal Investigator

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Johnson Research Cenbter

The University of Alabama in Huntsville

Huntsville, Alabama 35899

National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama
35812

NASA

Reply to Attn of: EM11(90-136) August 20, 1990

Called Marvin to cancel; should of been on new D.O. not this one.

TO: AP29E/Ms. Hamner

FROM: EM11/Mr. Smith

SUBJECT: Change of Contracting Officer's Technical Representative (COTR) for NAS8-36955, D.O. 53

Request that the COTR be changed from Mr. Todd MacLeod/EL62 to Mr. David R. McIntosh/EL64 on D.O. 53 under UAH Umbrella Contract, NAS8-36955. This request is based on the rationale delineated in the attached enclosure.

for Doris Higgs

Lawrence J. Smith
COR
NAS8-36955

Enclosure

National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812
AC(205)544-2121

NASA

Reply to Attn of: EL64(37-90)

TO: EM11/L.J. Smith

FROM: EL61/R.N. Stone

SUBJECT: Contracting Officer's Technical Representative (COTR) for NAS8-36955, Delivery Order 53, FES/VCGS Optical Studies

We would like to change the COTR on the subject contract from Mr. Todd MacLeod/EL62 to Mr. David R. McIntosh/EL64. The reason for this change is that this contract centers around the Fluid Experiment System/Ground Control Experiment Laboratory/Holographic Ground System (FES/GCEL/HGS) which Mr. McIntosh is the lead engineer.

For more information, contact Mr. Steve Ralston/EL64, at 544-1321.

Richard N. Stone

Richard N. Stone
Chief, Systems
Test Division

cc:
JA84/R.C. Ruff
EL62/B.J. Johnson/T.C. MacLeod
EL64/J.J. Lindsay/W.S. Ralston/D.R. McIntosh

TABLE OF CONTENTS

BACKGROUND

A major consideration in performing materials processing experiments in space is the ability to perform quantitative measurements on the experiments. In a number of crystal growth experiments, the primary analysis is the microstructural analysis following the flight.. Particularly in the case of metallic alloys, the opacity of the experiment ingredients makes it difficult to record data on the progress of the experiment. Only the final metallurgical analyses can be performed. Crystal growth experiments performed in the Fluid Experiment System (FES) Apparatus; however, is different in that the crystal growth is from a supersaturated water solution and is transparent to visible light. Hence quantititative data during the crystal growth is possible. The Holographic Ground System (HGS) Facility in rooms 22 & 123, Building 4708 has been developed to provide for ground based research in determining pre-flight parameters and analyzing the results from space experiments. UAH has researched the analysis aspects of the HGS and reports their findings here.

Some of the results presented here also occur in the Facility Operating Procedure (FOP), which contains instructions for power up, operation, and powerdown of the Fluid Experiment System (FES) Holographic Ground System (HGS) Test Facility for the purpose of optically recording fluid and/or crystal behavior in a test article during ground based testing through the construction of holograms and recording of videotape. The alignment of the optical bench components, holographic reconstruction and microscopy alignment sections were also included in the document for continuity even though they are not used until after optical recording of the test article) setup of support subsystems and the Automated Holography System (AHS) computer.

The HGS provides optical recording and monitoring during GCEL runs or development testing of potential FES flight hardware or software. This recording/monitoring can be via 70mm holographic film, standard videotape, or digitized images on computer disk. All optical bench functions necessary to construct holograms will be under the control of the AHS personal computer (PC). These include type of exposure, time intervals between exposures, exposure length, film frame identification, film advancement, film platen evacuation and repressurization, light source diffuser introduction, and control of realtime video monitoring. The completed sequence of hologram types (single exposure, diffuse double exposure, etc.) and their time of occurance can be displayed, printed, or stored on floppy disk posttest for the user.

EXPERIMENTAL RESULTS

1.0 OPTICAL BENCH LAYOUT

The HGS optical bench is illustrated in Figure 1. Note that the primary optical components are identified. In this figure and the following figures, the following abreviations are used.

L = lens
M = mirror
SM = steering mirror

TM = transverse mirror
BS = beamsplitter
TC = test cell
ND = neutral density filter
SF = spatial filter
HH = hologram holder

The laser beam enters from the middle left and propagates through the optical system. The beamsplitter BS1 provides the two optical paths for observation of hologrphic fringes at HH.

The reconstruction of a crystal growth experiment would be optimally configuered as shown in Figure 2.

2.0 OPTICAL BENCH ALIGNMENT

The optical alignment procedures as developed in this work are designed to optimize on spatial positioning of the optical beams propagating through the paths as defined in Figure 3. Place laser power meter detector (w/filter) in beam path between steering mirror two (SM2) and spatial filter (SF). Switch on laser power meter and position meter detector vertically and horizontally for maximum value. Then make adjusments to laser cavity for optimum output (~50mW).

Observe the height of steering mirror two (SM2) centerto be 15.5" using plexiglass calibration sticks (PCS) (top most mark). Adjust as necessary by loosening and turning adjustment knobs on periscope rod. This is now the basis for all other adjustments. Observe the beam spot on (SM2). If it is not centered then open laser cavity and translate laser tube laterally as linearly as possible till centered. Otherwise turn adjusment knobs on SM1 till centered.

Observe the beam spot on SM1. If it is not centered, either originally or from carrying previous steps, this is not a problem unless the spot is partially incident on nonreflective surfaces of the mirror mount. If this is occuring, adjustments will have to be made to the laser tube position. Of course once these are made the beam position will change on SM2 so repeat steps above.

Using the PCS, measure the beam vertically (15.5") between SM2 and turning mirror one (TM1). Use micrometer screw sticking out top of SM2 to correct height and observe beam spot on TM1. Use micrometer screw pointing out front of SM2 to center horizontally.

2.1 VERTICAL ALIGNMENT

2.1.1 The WAVEFRONT GENERATING LEG

Using PCS measure the beam vertically between TM1 and TM2. Use elevation adjustment knob on back of TM1 to correct height. Using the PCS measure the beam vertically between TM2 and collimating lens (L2). Use elevation adjustment knob on back of TM2 to correct height. Using the PCS measure the beam vertically between L2 and mirror one (M1). If beam height is not correct then turn both pairs of holding adjusments on L2 counter clockwise to loosen and allow L2 mount to slide freely on support rails. Then position as required to correct beam height. Using PCS measure the beam vertically between M1 and beamsplitter two (BS2). Use elevation adjustment knob on back of M1 to correct height.

2.2 MACH-ZEHNDER INTERFEROMETER

2.2.1 REFERENCE LEG

Using PCS measure the beam vertically between BS1 and M5. Use elevation adjustment knob on back of BS1 to correct height. Using PCS measure the beam vertically between M5 and M11. Use elevation adjustment knob back of M5 to correct height. Using PCS measure the beam vertically between M11 and BS3. Use elevation adjustment knob back of M11 to correct height. Using PCS measure the beam vertically between BS3 and M6. Use elevation adjustment knob back of BS3 to correct height. Using PCS measure the beam vertically between M6 and BS4. Use elevation adjustment knob back of M6 to correct height.

2.2.2 OBJECT LEG

Remove vacuum hologram holder, holographic camera, or test articles from object leg of MachZehnder Interferometer (between BS3 and M10). Using PCS measure the beam vertically between BS3 and M10. Use elevation adjustment knob back of BS3 to correct height. Using PCS measure the beam vertically between M10 and BS4. Use elevation adjustment knob back of M10 to correct height.

2.2.3 HOLOGRAPHIC REFERENCE LEG

Using PCS measure the beam vertically between BS2 and M2. Use elevation adjustment knob back of BS2 to correct height. Using PCS measure the beam vertically between M2 and M3. Use elevation adjustment knob back of M2 to correct height. Measure the beam vertically between M3 and M4. Use elevation adjustment knob back of M3 to correct height. Measure the beam vertically between M4 and the edge of the optical table. Use elevation adjustment knob back of M4 to correct height.

2.3.0 HORIZONTAL ALIGNMENT

2.3.1 WAVEFRONT GENERATING LEG

Observe beam spot on TM2. If it is not centered horizontally then use azimuth adjustment knob (NO GREEN STICKER) back of TM1 to correct angle. Observe beam spot on M1. If it is not centered horizontally then use azimuth adjustment knob back of TM2 to correct angle. Observe beam spot on L2. If it is not centered horizontally then turn micrometer adjusment that points toward the length of the table at the base of L2. Observe beam spot on BS1. If it is not centered horizontally then use azimuth adjustment knob back of M1 to correct angle.

2.3.2 MACH-ZEHNDER INTERFEROMETER

2.3.2.1 REFERENCE LEG

Observe beam spot on M5. If it is not centered hori zontally then use azimuth adjustment knob back of BS1 to correct angle. Observe beam spot on M11. If it is not centered horizontally then use azimuth adjustment knob back of M5 to correct angle. Observe beam spot on BS3. If it is not centered horizontally then use azimuth adjustment knob back of M11 to correct angle. Observe beam spot on M6. If it is not centered horizontally then use azimuth adjustment knob back of BS3 to correct angle.

2.3.2.2 OBJECT LEG

Observe beam spot on M10. If it is not centered horizontally then use azimuth adjustment knob back of BS3 to correct angle. Observe beam spot on BS4. If it is not centered horizontally then use azimuth adjustment knob back of M10 to correct angle.

2.3.2.3 HOLOGRAPHIC REFERENCE LEG

Observe beam spot on BS2. If it is not centered hori zontally then the mount will have to be unbolted and translated along the beam axis until correctly positioned. Observe beam spot on M2. If it is not centered horizontally then use azimuth adjustment knob back of BS2 to correct angle. Observe beam spot on M3. If it is not centered horizontally then use azimuth adjustment knob back of M2 to correct angle. Observe beam spot on M4. If it is not centered horizontally then use azimuth adjustment knob back of M3 to correct angle.

2.4.0 IMAGE SCREEN CENTERING

2.4.1 REFERENCE LEG

Refer to Figure 4 for the following steps. Push imaging lens (L3) along rail until out of beam path. Push schlieren probe assembly (SP) along rail until out of beam path. Place beam stop between M10 and BS4. Center beam spot on image screen using Aerotech Unidex IIIA stepper motor controller (Refer to unit manual for operation instructions) with the auxilliary switchbox set on M6 elevation and then M6 azimuth. Observe beam spot on BS4. If not centered then position BS4 mount to incoming beam using stepper motor contoller and switchbox set to BS4 transverse.

2.4.2 OBJECT LEG

Remove beam stop from between M10 and BS4. Align object beam spot on image screen with centered reference beam spot using stepper motor controller and switchbox set on BS4 elevation and then BS4 azimuth. At this time interference fringes should be seen at the intersection of the two spots on the image screen. If not, trace back along the beams to BS4 using a piece of paper as a target. If the beams diverge along the path then corrections must be made alternatively to M10 azimuth, BS4 longitude, and BS4 azimuth adjustments. DO NOT ADJUST THE REFERENCE LEG FROM M6. USE THIS AS THE BASIS FOR ALIGNING THE OBJECT BEAM. The goal is to get the object leg from M10 to overlap with the reference leg from M6 at the center of BS4. If constructing holograms (Refer to Figures 1 and 4.) proceed with 1.7, skip 1.8 and 1.9, and proceed with 1.10. If reconstructing holograms (Refer to Figure 6.) skip 1.7 and proceed with 1.8. If conducting holographic microscopy (Refer to Figure 7.) skip 1.7 and 1.8 and proceed with 1.9.

2.5 FILM CAMERA ALIGNMENT

Follow steps 7.1.8.1.1 thru 7.1.8.2.9 first, then return and continue from here. Set film camera pedestal base on table between the test article and M10 such that the top support plate is at 22.5 ° off horizontal (length of table). Set film camera motor drive on positioning pins of base with drive electrical connector and vacuum nozzle facing away. Place film camera magazine on motor drive by pressing release button and positioning camera aperature towards the test article. Position base with reference and object beams incident at approximately film center of the magazine aperature. Lock down base with four (4) 1/420 hex screws. Loosen the four (4) nuts and bolts holding the camera pedestal's top two (2) support plates. Block holographic reference beam with beam stop. Position camera by sliding top support plate in the di rection of its adustment slots until the object beam spot is centered. Remove beam stop from holographic reference beam and block the object beam. Position camera by sliding top support plate in the direction of the bottom support plate slots until the reference beam spot is centered. Remove the beam stop from object beam path. Verify that the base top support is straight (perpendicular to lower support plate). Make any final needed adjustments to get both interfering beams to be incident at the camera aperature center. Tighten holding screws at top platforms of camera base.

2.5.0 VACUUM HOLOGRAM HOLDER ALIGNMENT

2.5.1 M4 ALIGNMENT

Block holographic reference beam with beam stop. Press release button on rotation stage and rotate HH1 until perpendicular to incoming object beam. While looking back through HH1 glass platen, compare object beam spot reflection on BS3 with originating beam spot. Turn angular adjustment knob on rotation stage until two spots meet. Remove beam stop from reference beam and block object beam.

Press HH1 rotation stage release button and rotate mount clockwise 45 . While looking back through HH1 glass platen, compare reference beam spot reflection on M4 with originating beam spot. Turn azimuth adjustment knob on M4 (no green sticker) until two spots meet. Press HH1 rotation stage release button and rotate mount counterclockwise 22.5.

2.5.2 FINAL POSITIONING

Block holographic reference beam with beam stop.Position HH1 assembly in a perpendicular direction to the incoming object beam until it is centered on glass platen. Remove beam stop from reference beam and block object beam. Position HH1 in the direction of the object beam path (if it were not blocked) until the reference beam is centered. Remove beam stop from reference beam path.
1.8.3.6 Make any fine adjustments necessary to achieve both beams incident at the glass platen center. Tighten all eight (8) 1/420 hex screws on upper and lower base plates.

2.6.0 MICROSCOPE ALIGNMENT

2.6.1 AUXILLIARY MIRROR INSTALLATION

Position mirror assembly (sixinch mirror,support post, and xy translation base) on optical table in front of BS1 such that the incoming beam spot is centered horizontally and vertically centered. Install and lock down two (2) 1/420 hex screws at mount base to optical table top. Tighten the other two (2) 1/420 hex screws at top plate of mount base. Loosen locking screw on support post and allow mirror to be held by lock ring only. This will keep mirror at 15.5" but allow freedom of rotation.

2.6.2 MICROSCOPE HOLOGRAM HOLDER

Position microscope hologram holder (glass plate sand wich holder rather than vacuum) on optical bench at an approximate position between BS3 and the test article position. Align base plates with long side almost flush to test article loading rails. Load glass platen sandwich pair into frame and insert into holder.
Press release button on rotation stage and rotate holder frame parallel to the length of the table. Insert two (2) 1/420 hex screws (mount will not accept all four screws when mounted in this position) into base plate but do not tighten down.

2.6.3 RECONSTRUCTION BEAM ALIGNMENT

Extend an imaginary line from the auxilliary mirror center along the length of the table until it meets the intersection point of an imaginary line extended horizontally from the hologram holder. Measure this length (table top hole matrix is 1" x 1"). Place the tip of the tape at the imaginary intersection point and extend the length towards the hologram holder glass platen center. Reposition hologram holder mount until tape measure is correctly centered. Reinstall hex screws if necessary and tighten in place. Turn auxilliary mirror until laser beam is incident at hologram holder glass platen center. Tighten auxilliary mirror locking ring screw.

2.6.4 MICROSCOPE INSTALLATION

Place microscope assembly on table at edge next to M5 such that the objective lens is approximately in line with the hologram holder center. stall four (4) 1/420 hex screws into base plate but don't tighten. Loosen hex screws holding upper baseplate if not already. Install hologram into holder plates to reconstruct real image to microscope. Reposition microscope via image in stereo eyepieces and tighten all eight hex screws on base plates.

2.7.0 SPATIAL FILTER INSTALLATION

Located at rear of SF support base are two micrometer adjustment screws. Correct for vertical error with the adjustment screw which projects vertically and angular error with the adjusment screw which projects toward the long end of the optical table. Replace the objective lens barrel assembly into its holding ring at the rear of the SF. The narrow end inserts first with the adjustable aperature facing toward the incoming laser beam. Tighten objective lens holding screw which sticks out vertically and is adjacent to the lens assembly.

Close objective lens barrel aperature by rotating the adjustment pin clockwise. Observe the incoming beam spot on the closed aperature. Adjust the aperature to the incoming beam vertically by turning the left thumbscrew under the opening where the beam is exiting. Adjust the aperature horizontally by turning the right thumbscrew. Open objective lens barrel aperature fully by rotating the adjustment pin counterclockwise. Turn counterclockwise the outer ring which encircles the exit opening of the SF until it stops. Replace the pinhole assembly by screwing it clockwise into the hole where the beam is exiting from the SF. Turn adjustment screws on top and side of pinhole holding frame to achieve maximum brightness at pinhole output. Alternate turning the pinhole outer ring and holding frame adjustment screws until the brightest and cleanest output is achieved. A white target placed in back of optical table aperature one (A1) will aid this effort.

3.0.0 REALTIME IMAGE RECORDING INITIALIZATION.

3.1 0 AUXILLIARY MIRROR SYSTEM INSTALLATION

Install a six inch diameter beamsplitter between the test article and the film camera. Center the beamsplitter vertically by loosening and re-tightening the post locking screws. Rotate the beamsplitter counterclockwise until the incoming object beam is angling back just past the test article edge. Install a 4x6 inch ectangular mirror to intercept the beam reflecting from the installed beamsplitter and send it back horizontal down the length of the table. Install an eightinch diameter mirror behind M10 to intercept the beam reflecting from the 4x6 inch mirror and send it toward BS4. Using a 3/16inch hex key, loosen and remove the locking bolt projecting out the front of BS4. Rotate BS4 to reflect the incoming beam to the image screen via L3. Replace and tighten the BS4 locking bolt. Note: Comparing observations will have to made between the images to the holographic film camera and the image screen to achieve a compromise between the two. Usually the film camera image has priority at the expense of the image screen image. Tighten down all installed components once their final positions have been determined if not already done.

4.0.0 Using the above procedures, a number of tests were run in which the imaging conditions expected for the space-based experiments were duplicated. Both the triglysine sulfate and CAST experiments were performed at the HGS on several ocassions. The payload specialists who are responsible for the FES during their space activity were involved in a number of the tests as part of their training.

Several goals for this phase of the HGS studies were to optimize upon the holographic resolution so as to be able to discriminate between small particles observed in the CAST experiments and to attain a better automated methodolgy for analyzing the holograms. The ultimate resolution obtained with the system, after optimizing all optical systems, was never fully determined. The small particles, which were placed in the solution (< 400 m), consistently clumped together into larger particles. More study is required for this determination.

The automated analysis procedures appear to be better defined with the software generated by Dr. Howard Brooks of Depauw University. UAH students have worked with the program during the final phase of this effort and feel that this analytical capability far exceeds the previous methodologies.

SUMMARY

The Holographic Ground Station continues to be a versatile ground-based facility for FES experimental verifiacation. The ultimate capabilities are limited by current hardware and software available to the facility. experimental The procedures defined in this work appear to improve upon the ability of operator personnel to optimize the optical system. Newer software as developed by Depauw University appear to make the software more amenable to automated data reduction.

ACKNOWLEDGEMENTS

This study was performed primarily by the two UAH students, Jeffrey Haight and Tammy Self. Both worked long and hard toward achieving the facility goals. We are indebted to Dave MacIntosh and Todd Macleod who provided much insight into the HGS operational aspects.

FIGURE 1. HGS OPTICAL BENCH LAYOUT
RECORDING A HOLOGRAM

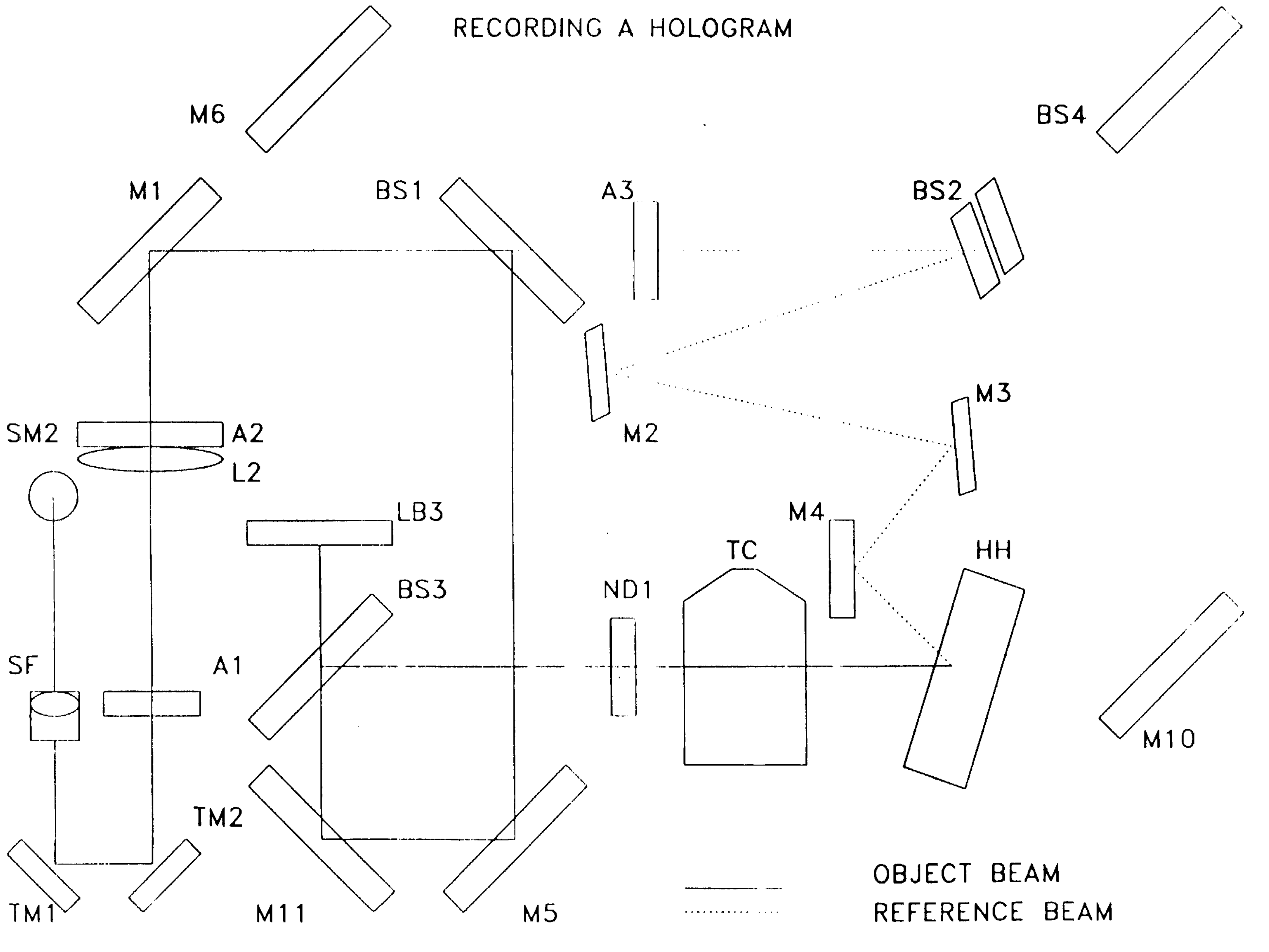
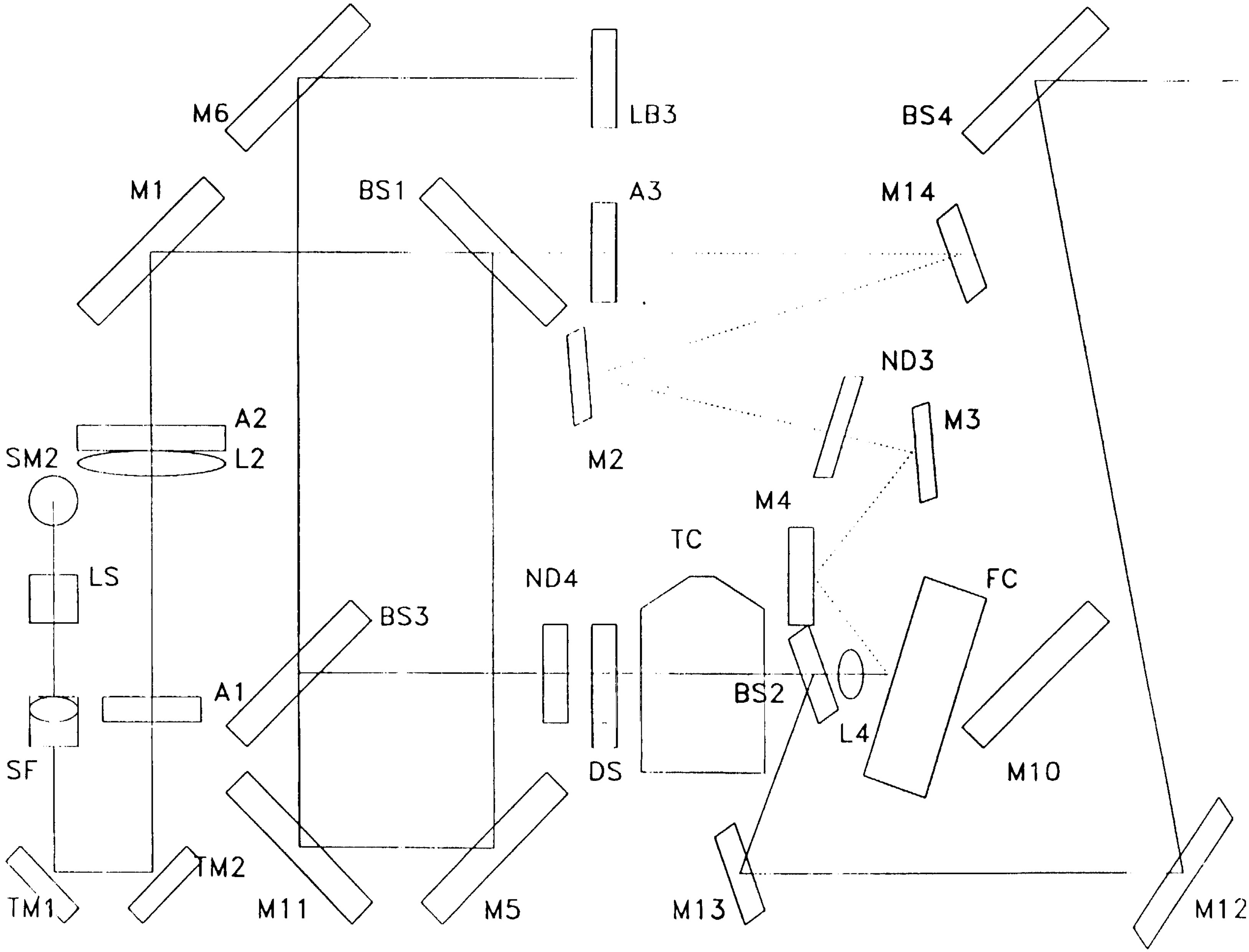


FIGURE 2. HGS HOLOGRAPHIC CONSTRUCTION



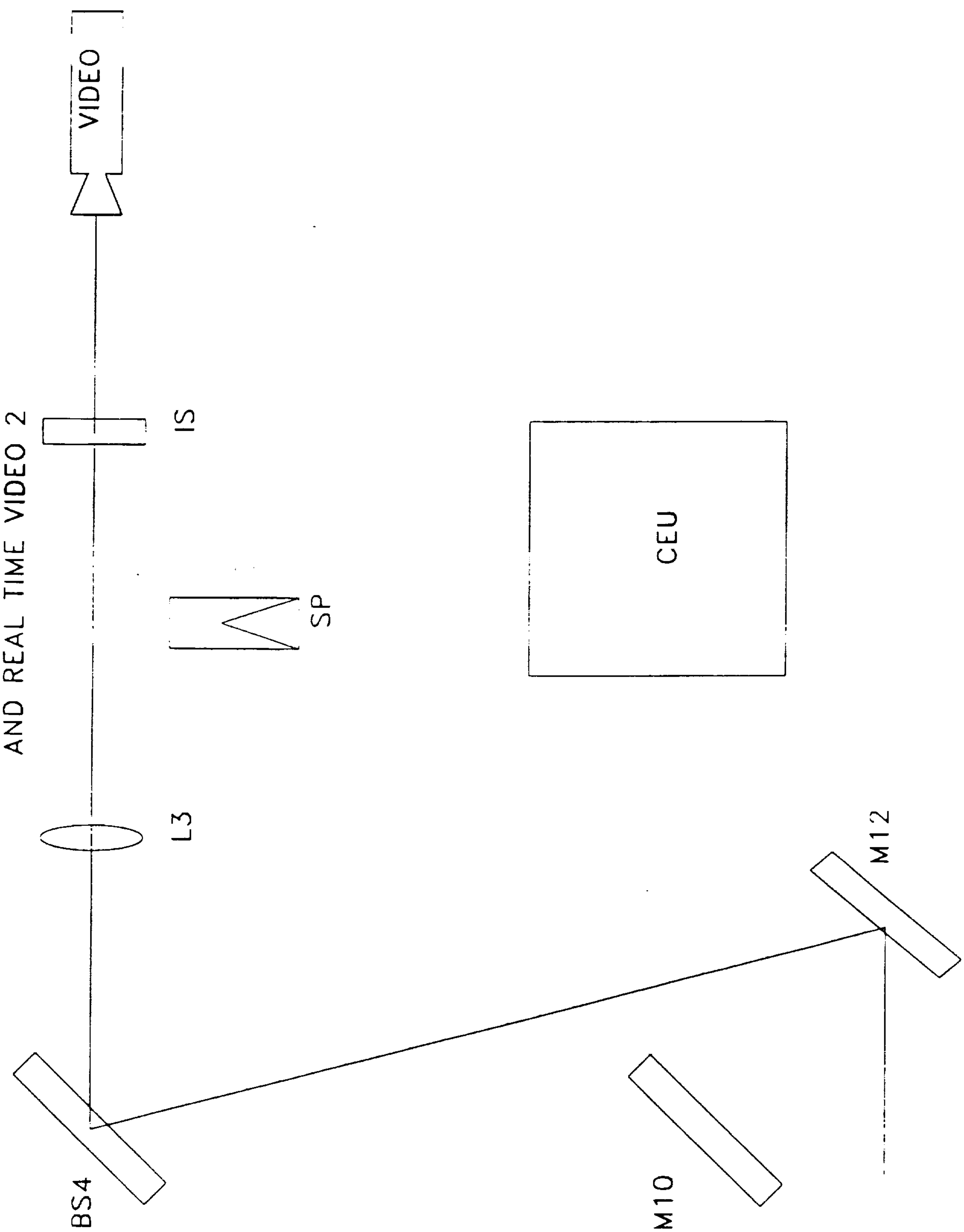


FIGURE 3. HGS HOLOGRAPHIC CONSTRUCTION AND REAL TIME VIDEO 2

FIGURE 4. RLAL TIME CLASSICAL
MACH-ZEHNDER INTERFEROMETER 1

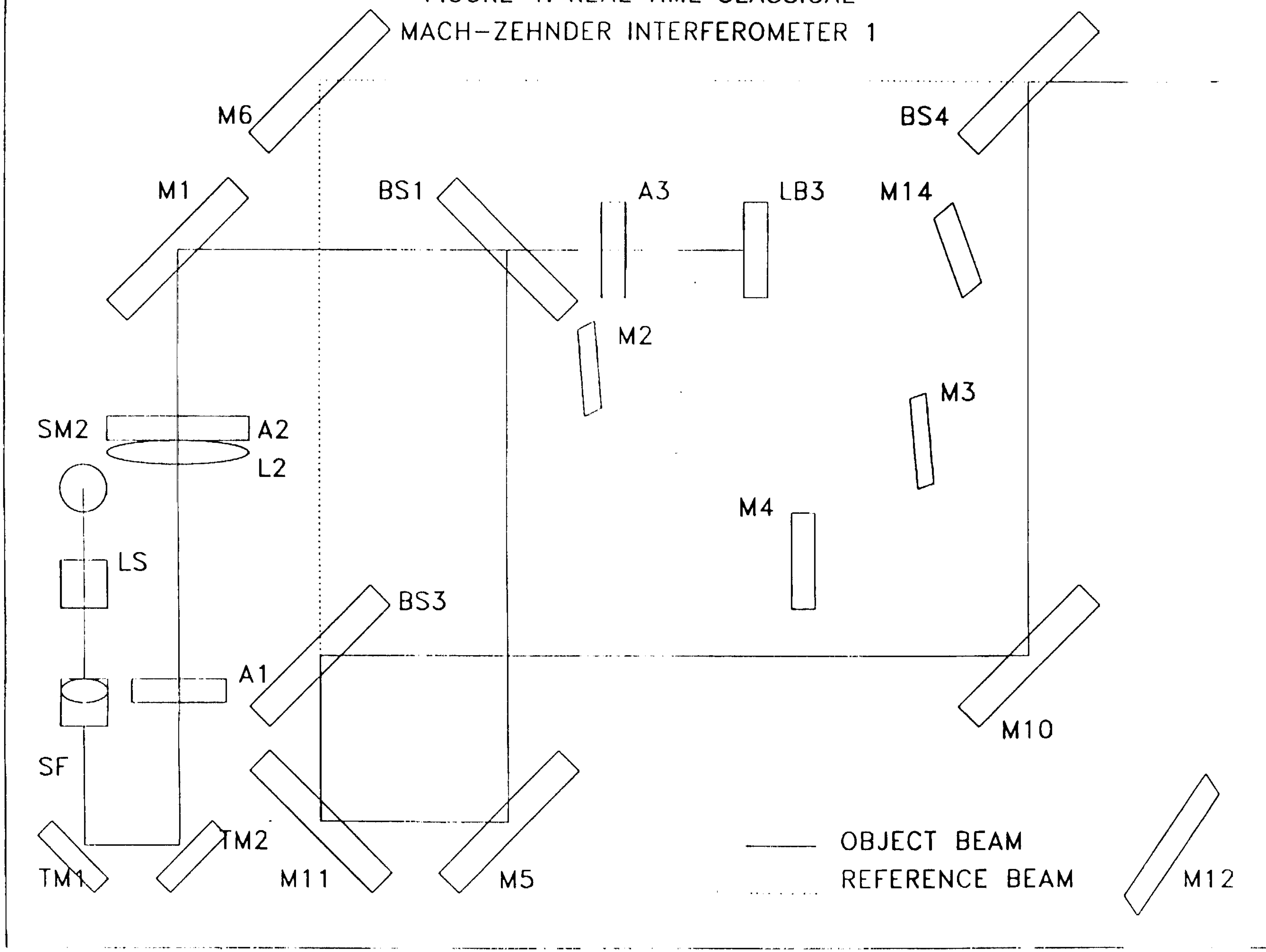


FIGURE 5. HGS REAL TIME CLASSICAL
MACH–ZEHNDER INTERFEROMETER 2

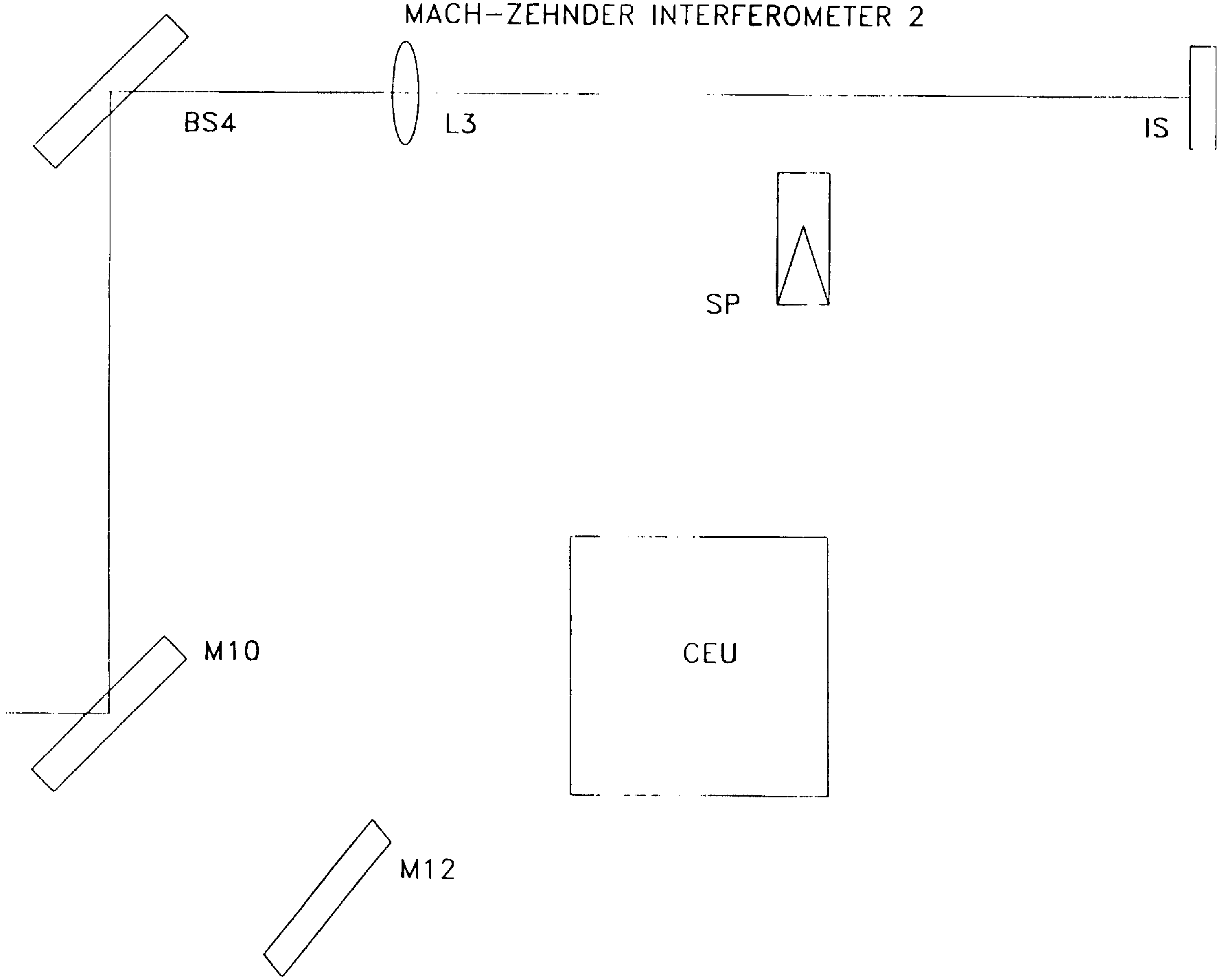


FIGURE 6. HGS HOLOGRAM RECONSTRUCTION

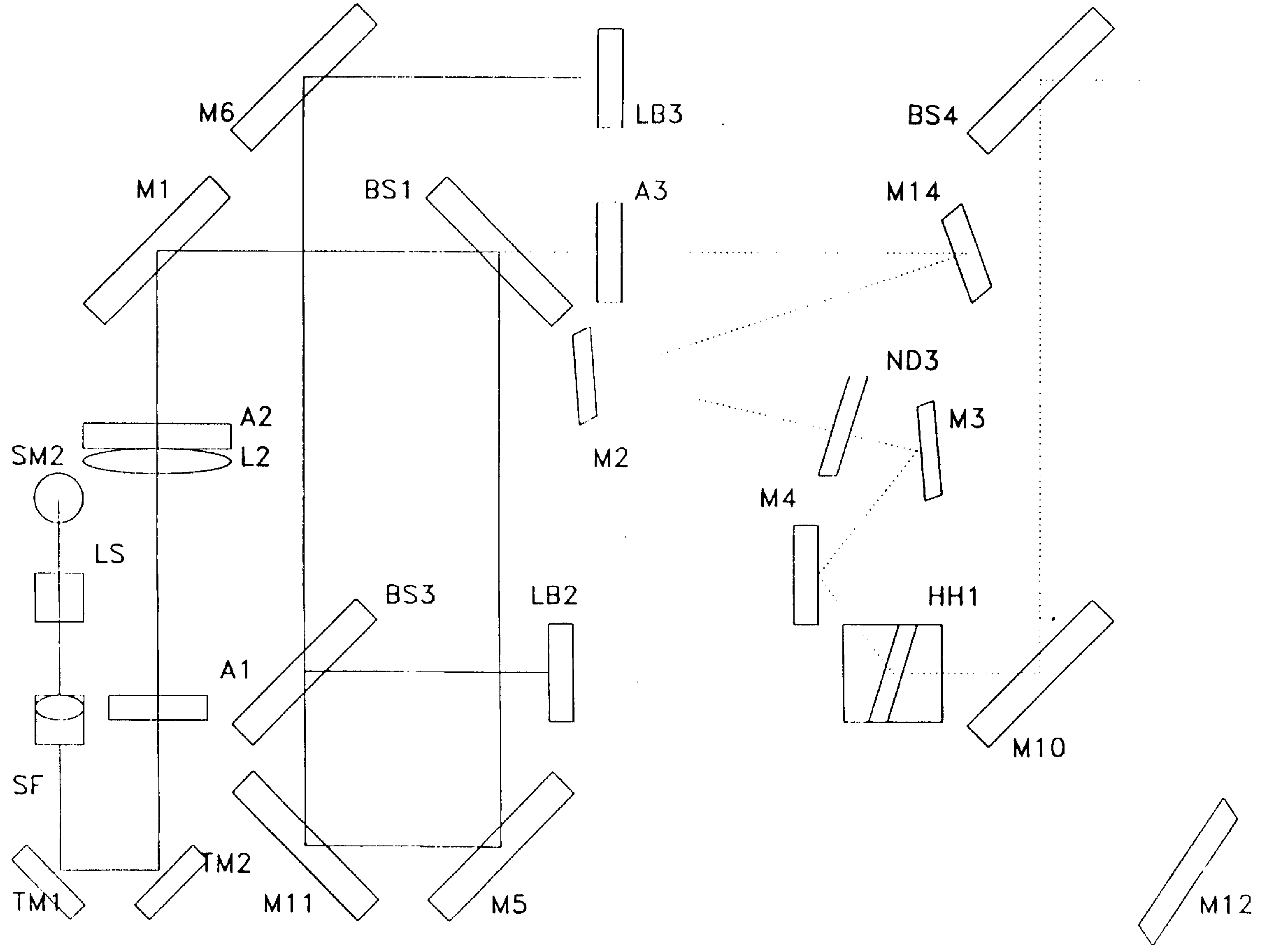


FIGURE 7. HGS MICROSCOPY WITH RECONSTRUCTED HOLOGRAM